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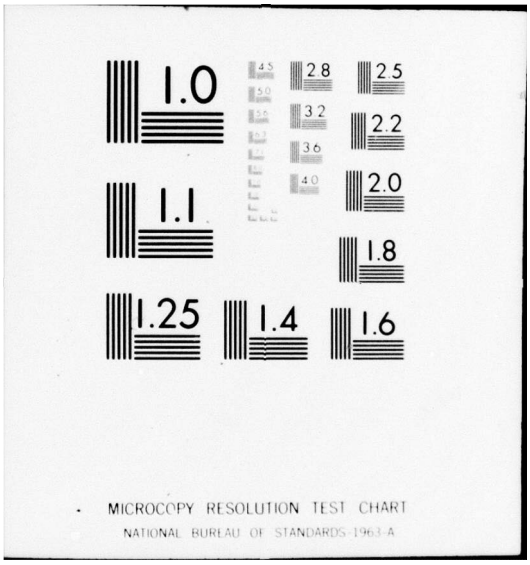
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UNITED STATES AIR FORCE
AIR WEATHER SERVICE (MAC)

USAF ENVIRONMENTAL
TECHNICAL APPLICATIONS CENTER

SCOTT AIR FORCE BASE, ILLINOIS 62225

Report 7584A

APPENDIX 3 TO USAFETAC REPORT 7584

Effects on Infrared Transmission

by

Laurence D. Mendenhall, Capt, USAF

May 1977

Review and Approval Statement

This report approved for public release. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

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John W. Oliver

JOHN W. OLIVER, Maj, USAF
Chief, Electromagnetic Propagation Section

FOR THE COMMANDER

Walter S. Burgmann

WALTER S. BURGMANN
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of an analysis of the transmissivity in the 2.95 μm band through the stratosphere and upper troposphere. Comparisons are made between transmissivity calculations from the observed water-vapor profiles and the profiles constructed from three models. These comparisons showed the new model yielded a significant reduction in error in the transmissivity for a slant path from the -40°C temperature level

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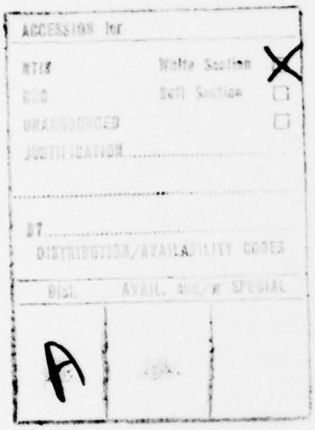
out to space (100 km altitude) from that produced by two old models.



APPENDIX 3 TO USAFETAC REPORT 7584
Effects on Infrared Transmission

Introduction

This appendix to USAFETAC Report 7584[1] presents results of an analysis of the transmissivity in the 2.95 μm band through the stratosphere and upper troposphere. Specifically, the transmissivities were determined for a slant path (zenith angle=80°) from a height of 100 km to the height of the -40°C temperature level. The analysis was performed on the same 101 NRL frost-point soundings that were used in the development of the water-vapor model as described by Mendenhall, Stanton, and Henderson in USAFETAC Report 7584[1].

Method

The purpose of this analysis was to determine the relationship between total transmissivity, i.e., transmissivity resulting from all absorbers, to the water-vapor equivalent-absorber amount. Such a relationship would permit the calculation of the total transmissivity directly from the water-vapor and temperature profile. The LOWTRAN 3[2] computer program was used to determine this relationship by changing the water-vapor amounts contained in the 1962 U. S. Standard Atmosphere[3], model 6, in the 10 to 20 km region. A total of 12 different water-vapor profiles were made, resulting in 12 values of water-vapor equivalent-absorber amounts. LOWTRAN 3 runs on these 12 profiles for a slant path having a zenith angle of 80° and altitude interval from 100 to 10 km, yielded the corresponding total transmissivities. These results, appearing in Table 1, were then used in a separate program, TOTRAN, to compute the transmissivity in each of the 101 NRL frost-point soundings as well as in these same soundings, but with the observed water-vapor profiles above the -40°C temperature level replaced with the modeled profiles from the new model and the two old models. Calculation of the water-vapor equivalent-absorber amount followed the method employed in LOWTRAN 3[1]

$$w(z) = 0.1\rho_v(z)\left[\left(\frac{P(z)}{1013}\right)\left(\frac{273}{T(z)}\right)^{\frac{1}{2}}\right]^{0.9} \qquad (1)$$

where w is the equivalent absorber amount in gm/cm^{2}km, ρ_v is the absolute humidity in gm/m^3, P is the pressure in millibars, and T is the temperature in °K. We then calculated the total equivalent absorber amount W along the slant path:

$$W = \sum_{i=1}^{m-1} \frac{\Delta s_i\left[w(z_i) - w(z_{i+1})\right]}{\ln\left[w(z_i)/w(z_{i+1})\right]} \qquad (2)$$

where Δs_i is the path length through the layer, $w(z_i)$ is the water-vapor equivalent absorber amount at each level, and m is the number of levels. Program TOTRAN used logarithmic interpolation of the equivalent-absorber amount and transmissivity data contained in Table 1.

Results

Tables 2 and 3 show the transmissivities and errors in transmissivities for the slant path (zenith angle=80°) from 100 km to the tropopause and to the T =-40°C level, respectively, for five of the 101 soundings. The error is computed from the difference between the observed and modeled transmissivity divided by the observed, and multiplied by 100. USAFETAC Report 7584[1] shows a comparison of the frost-point and precipitable-water profiles for these same soundings. Figure 1 shows the relative frequency of the transmissivity for two "old" models and the new model for the 80° slant path from 100 km to the T = -40°C level. Tables 4 and 5 summarize some of the statistics on errors in transmissivities for the same data. The model currently used, the frost-point depression model, resulted in transmissivity errors of 10 percent or more in about 28 percent of the cases, while the same errors in the new model occurred in only 2 percent of the cases. Eighty percent of the cases showed errors of 5 percent or less using the new model, but only 32 percent of the time did the frost-point depression model exhibit similarly small errors.

References

[1] Mendenhall, L. D., Stanton, T. E., and Henderson, H. W.: "A Model for Describing the Atmospheric Water-Vapor Profile Above the -40°C Temperature Level," USAFETAC Report 7584, 20 August 1975, 84 p.

[2] Selby, J. E. A. and McClatchey, R. A.: "Atmospheric Transmittance from 0.25 μm to 28.5 μm: Computer Code LOWTRAN 3", AFCRL-TR-0255, 7 May 1975.

[3] U. S. Standard Atmosphere, 1962, U. S Government Printing Office, Washington, D. C., 278 p.

Table 1. Total Transmissivity in the 3390-3720 cm^{-1} Band as a Function of the Water-Vapor Equivalent-Absorber Amount for a Slant Path with Zenith Angle = 80° from 100 km to 10 km.

Equivalent-Absorber Amount ($gram/cm^2$)	Total Transmissivity
1.0×10^{-5}	0.4600
2.29	0.4560
7.59	0.4510
2.66×10^{-4}	0.4402
9.87	0.4182
2.36×10^{-3}	0.3947
3.99	0.3753
6.14	0.3570
9.32	0.3364
1.63×10^{-2}	0.3045
2.26	0.2836
3.70	0.2500

Table 2. Model Comparisons of Transmissivities and Errors for Path From 100 km Height to the Tropopause Level for Zenith Angle = 80°.

			Transmissivities Error (percent)		
Location	Date/Time	Observed	Mixing-Ratio Model	Frost-Point Dep Model	New Model
Thule, Greenland	22 Aug 65 1925Z	0.395	0.381 -3.7	0.405 2.4	0.402 1.5
Washington, DC	16 Jan 64 1800Z	0.423	0.409 -3.3	0.417 -1.4	0.418 -1.0
Washington, DC	25 Aug 64 1730Z	0.437	0.449 2.6	0.449 2.6	0.445 1.8
Washington, DC	29 Nov 67 1610Z	0.422	0.419 -0.60	0.424 0.57	0.424 0.58
Washington, DC	19 Dec 67 1700Z	0.444	0.449 1.08	0.449 1.08	0.446 0.28

Note: Transmissivities in the table were rounded, but they were not rounded for error calculations.

Table 3. Model Comparisons of Transmissivities and Errors for Path From 100 km Height to the T = -40°C Level for Zenith Angle = 80°.

			Transmissivities / Error (percent)		
Location	Date/Time	Observed	Mixing-Ratio Model	Frost-Point Dep Model	New Model
Thule, Greenland	22 Aug 65 1925Z	0.253	0.251 -0.94	0.283 11.6	0.266 5.2
Washington, DC	16 Jan 64 1800Z	0.289	0.309 3.8	0.317 9.6	0.307 6.3
Washington, DC	25 Aug 64 1730Z	0.346	0.339 -2.0	0.343 -0.76	0.345 -0.25
Washington, DC	29 Nov 67 1610Z	0.285	0.309 8.4	0.328 14.9	0.315 10.4
Washington, DC	19 Dec 67 1700Z	0.319	0.328 2.5	0.332 4.0	0.330 3.3

Note: Transmissivities in the table were rounded, but they were not rounded for error calculations.

Table 4. Model Comparisons of Statistics of Error in Transmissivity from 100 km to the T = -40°C Level for Zenith Angle = 80°.

101 NRL Soundings 1964 - 1973

Error (percent)	Mixing-Ratio Model	Frost-Point Dep Model	New Model
Mean	2.4	7.2	0.9
Standard Deviation	5.1	4.9	4.4
Minimum	-10.5	-6.3	-12.1
Maximum	13.5	18.4	19.9

Table 5. Model Comparisons of Absolute Value of Error in Transmissivity from 100 km to the T = -40°C Level for Zenith Angle = 80°.

101 NRL Soundings 1964 - 1973

	Frequency (percent)		
Absolute Error	Mixing-Ratio Model	Frost-Point Dep Model	New Model
0 to ± 5%	64.35	28.71	77.23
± 5% to ±10%	27.73	41.59	14.80
±10% to ±15%	7.92	23.76	1.98
±15% to ±20%	0.00	5.94	0.99
TOTAL	100.00	100.00	100.00

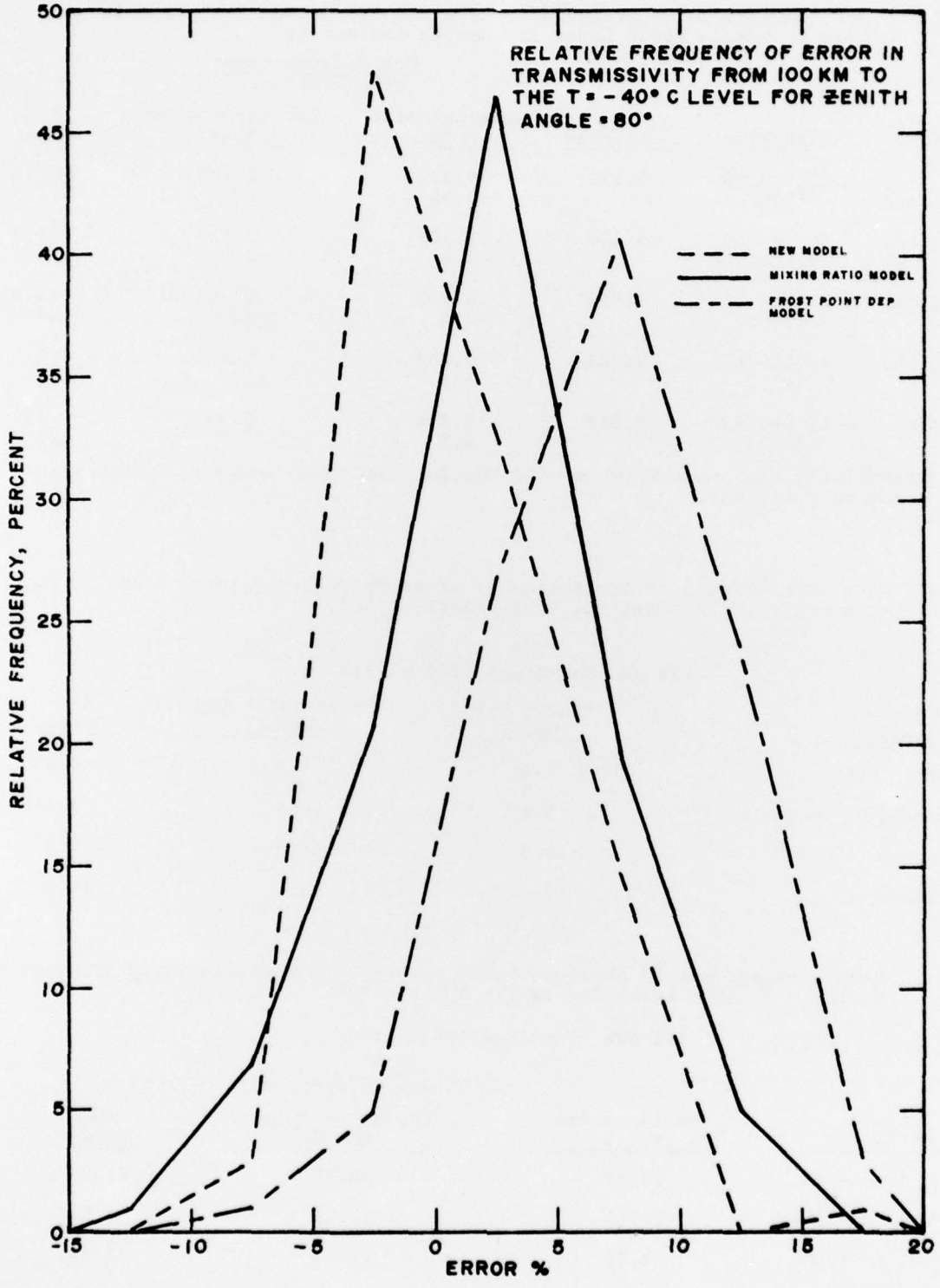


Figure 1. Relative Frequency of Error in Transmissivity from 100 km to the T=-40°C Level for Zenith Angle = 80°.